

Laboratory Evaluation

PurpleAir PA-I Indoor



Background

Three **PurpleAir PA-I Indoor** (Hereinafter PA-I Indoor) sensors (units IDs: 29D1, A3CA and BB9F) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (02/15/2018 to 04/25/2018) under ambient environmental conditions and have now been evaluated in the South Coast AQMD Chemistry Laboratory under controlled artificial aerosol concentration/size range, temperature, and relative humidity. The same three PA-I Indoor units were tested both in the field (1st stage of testing) and in the laboratory (2nd stage of testing).

- **PA-I Indoor (3 units tested):**

- Particle sensor (**optical; non-FEM**)
- PM sensor: Plantower PMS1003
- Each unit measures: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu g/m^3$) Temperature ($^{\circ}F$)
- **Unit cost: ~\$180**
- Time resolution: 2-min (during lab evaluation)
- Units IDs: 29D1, A3CA and BB9F

- **GRIMM (reference method):**

- Optical particle counter
- **FEM $PM_{2.5}$**
- Uses proprietary algorithms to calculate total PM, $PM_{2.5}$, and PM_{10} mass conc. from particle number measurements
- **Cost: ~\$25,000**
- Time resolution: 1-min

- **TSI APS 3321 (reference method for PM_{10} mass):**

- Aerodynamic particle sizer
- Measures particles from 0.5 to 20 μm
- Uses a patented, double-crest optical system for unmatched sizing accuracy
- **Cost: ~\$50,000**

Evaluation results guideline

- PurleAir PA-I Indoor vs GRIMM PM_{1.0} mass concentration
- PurleAir PA-I Indoor vs FEM GRIMM PM_{2.5} mass concentration
- PurleAir PA-I Indoor vs GRIMM vs APS PM₁₀ mass concentration



PurpleAir PA-I Indoor

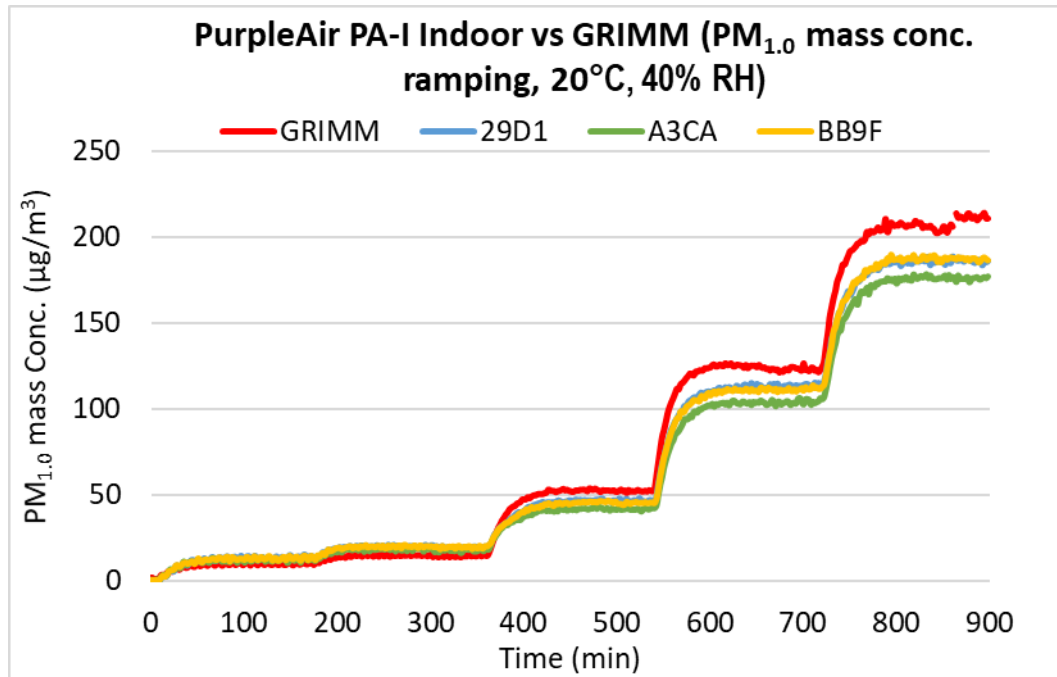


TSI APS 3321

Evaluation results for PM_{1.0} mass concentration

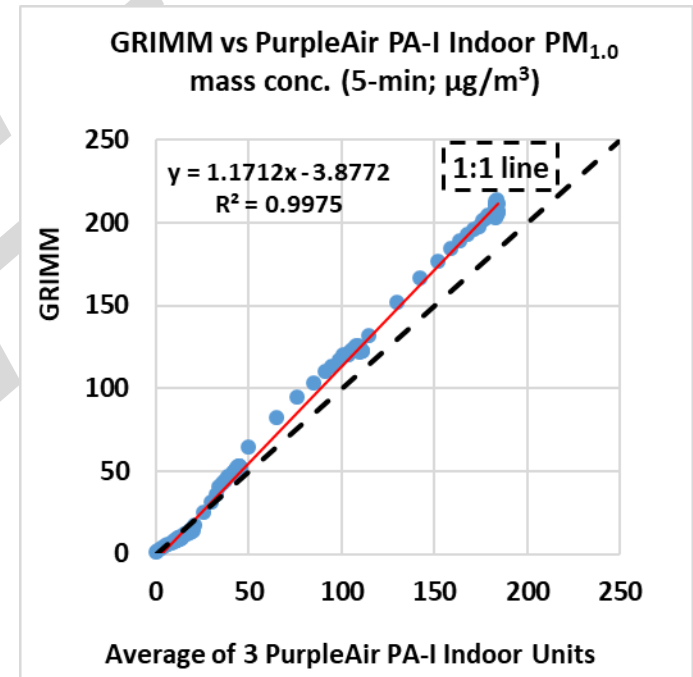
PurpleAir PA-I Indoor vs GRIMM

PA-I Indoor vs GRIMM (PM_{1.0} mass conc.)



- The PA-I Indoor sensors tracked well with the PM_{1.0} concentration variation as recorded by the GRIMM in the concentration range of 0 - ~200 $\mu\text{g}/\text{m}^3$.

Coefficient of Determination



- The PA-I Indoor sensors showed very strong correlations with the GRIMM PM_{1.0} mass conc. ($R^2 > 0.99$).

PA-I Indoor vs GRIMM PM_{1.0} Accuracy

- Accuracy (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m ³)	GRIMM (µg/m ³)	Accuracy (%)
1	12.8	9.5	65.1
2	18.8	14.2	67.5
3	44.5	52.1	85.3
4	109.5	123.1	89.0
5	183.3	199.1	92.1

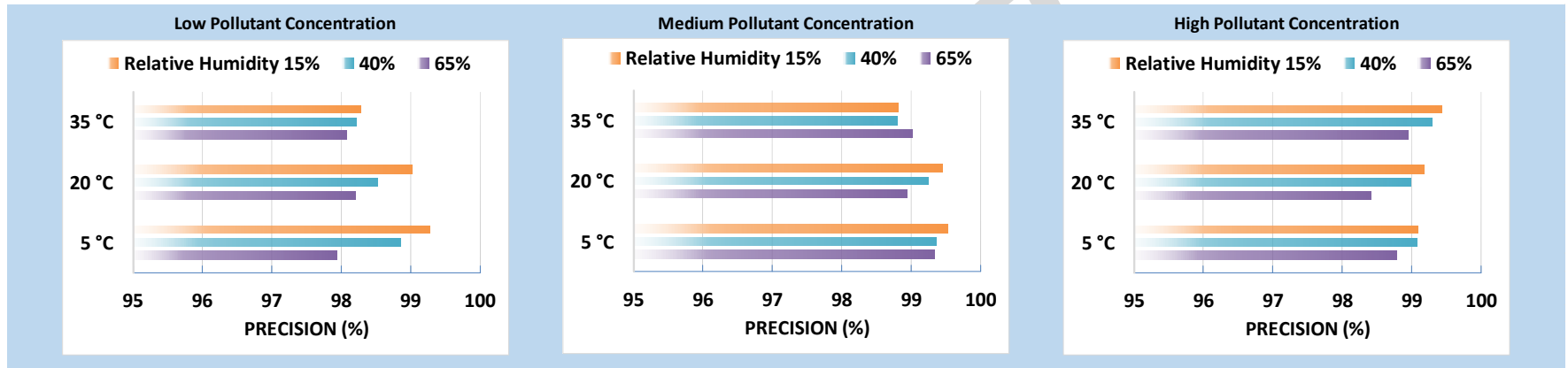
- The PA-I Indoor sensors underestimated GRIMM PM_{1.0} at mass concentrations > 50 µg/m³, while they overestimated mass concentrations < 50 µg/m³. The accuracy of the PA-I Indoor sensors increased as PM_{1.0} mass concentrations increased.

PA-I Indoor : Data Recovery and intra-model variability

- Data recovery for PM_{1.0} mass concentration from all units was 100%
- Low PM_{1.0} measurement variations were observed between the PA-I Indoor sensors

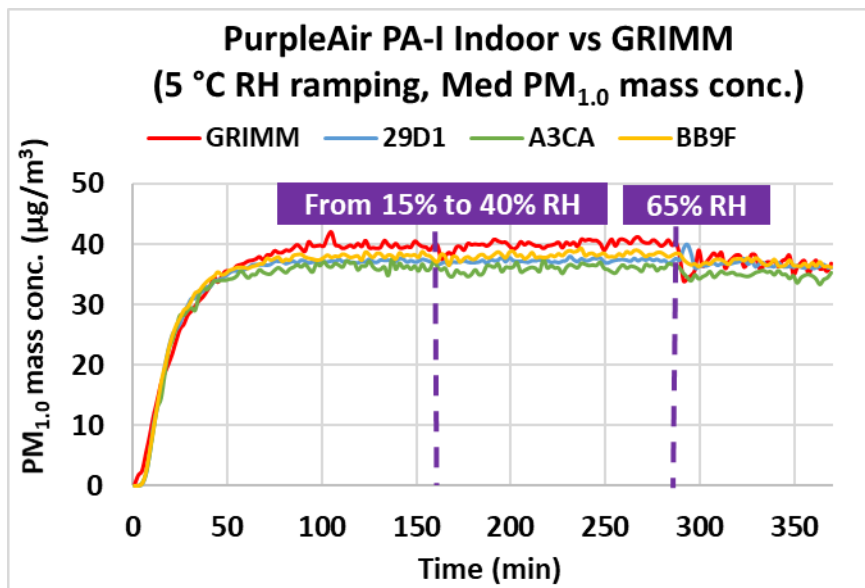
PM_{1.0} Precision: PA-I Indoor

- Precision (Effect of PM_{1.0} conc., Temperature and Relative Humidity)



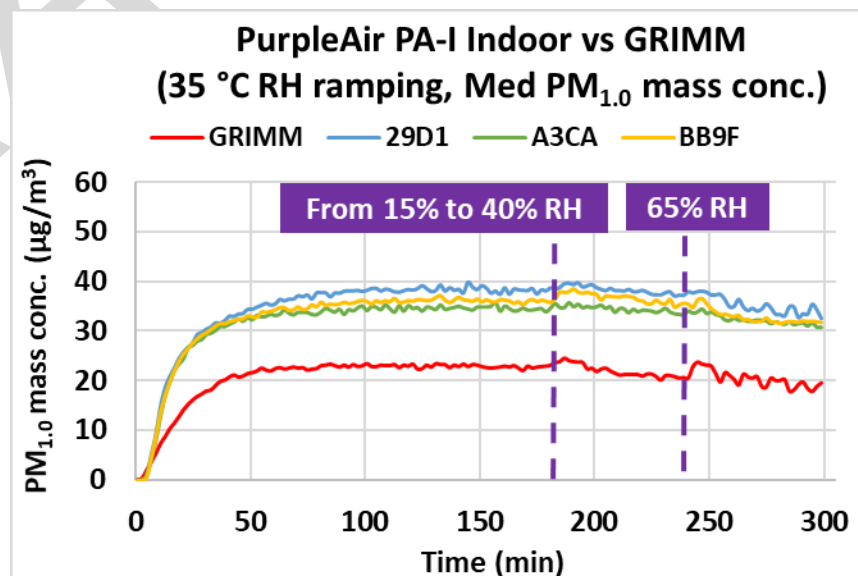
- Overall, the PA-I Indoor sensors showed high precision for all of the combinations of low, medium and high PM_{1.0} conc., T and RH.

PA-I Indoor PM_{1.0}: Climate Susceptibility



**Low Temp – RH ramping
(medium conc.)**

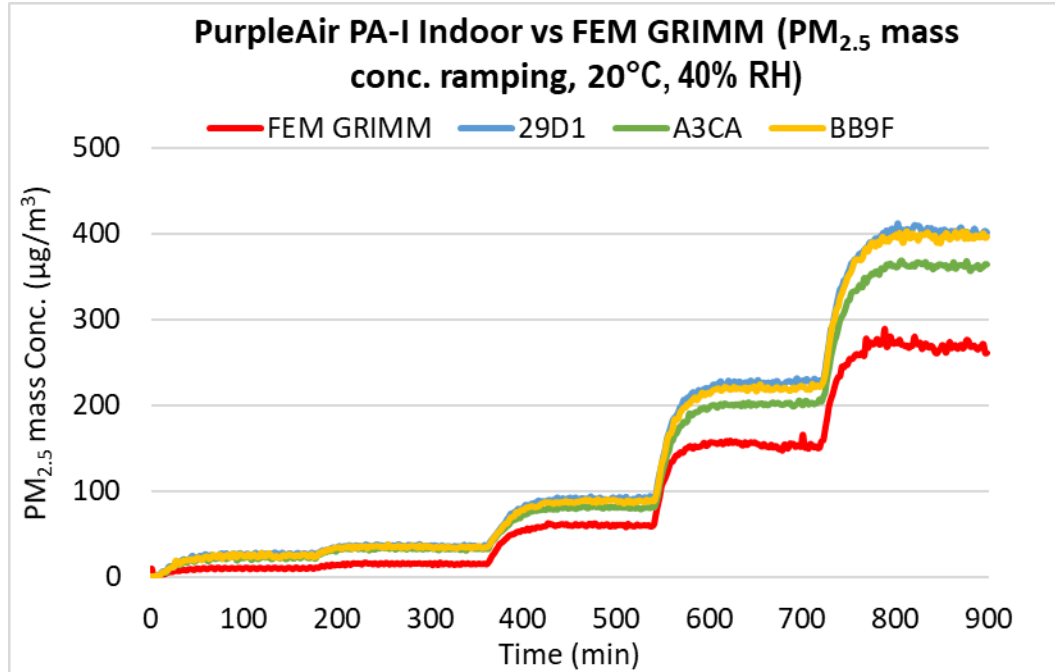
**High Temp – RH ramping
(medium conc.)**



Evaluation results for PM_{2.5} mass concentration

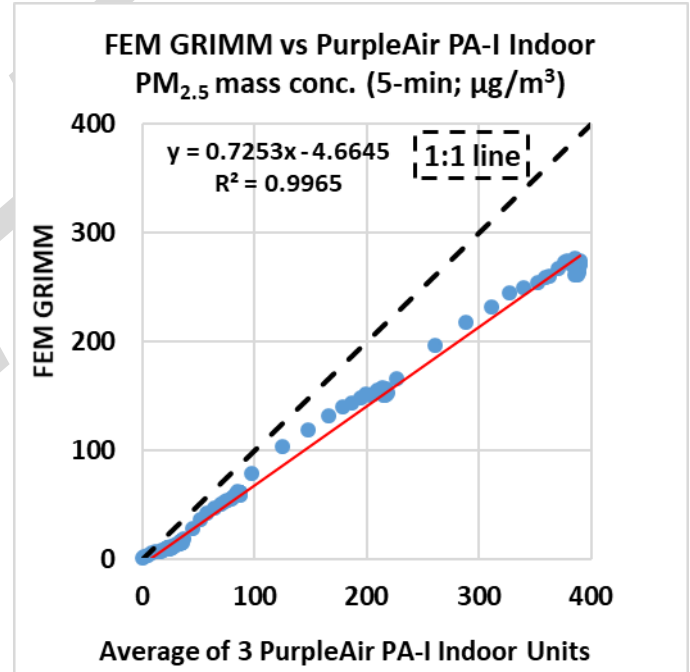
PurpleAir PA-I Indoor vs FEM GRIMM

PA-I Indoor vs FEM GRIMM (PM_{2.5} mass conc.)



- The PA-I Indoor sensors tracked well with the concentration variation as recorded by the FEM GRIMM in the concentration range of 0 - ~300 µg/m³.

Coefficient of Determination



- The PA-I Indoor sensors showed very strong correlations with the FEM GRIMM PM_{2.5} mass conc. ($R^2 > 0.99$)

PA-I Indoor vs FEM GRIMM PM_{2.5} Accuracy

- Accuracy (20 °C and 40% RH)

Steady state #	Sensor Mean (µg/m ³)	FEM GRIMM (µg/m ³)	Accuracy (%)
1	24.4	10.3	-37.1
2	33.9	15.3	-21.5
3	86.3	60.2	56.6
4	216.1	152.6	58.3
5	387.4	255.2	48.2

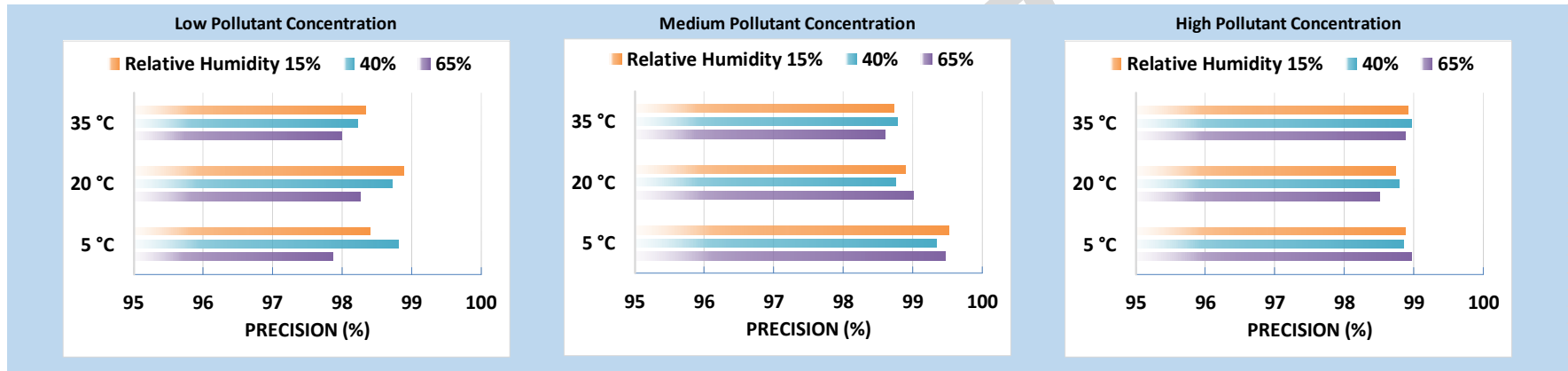
- The PA-I Indoor sensors overestimated FEM GRIMM PM_{2.5} mass concentration at 20 °C and 40% RH. The accuracy of the PA-I Indoor sensors was negative at low PM_{2.5} mass conc. and fairly constant (48% to 57%) for PM_{2.5} mass concentrations > 50 µg/m³.

PA-I Indoor : Data Recovery and intra-model variability

- Data recovery for PM_{2.5} mass concentration from all units was 100%
- Low PM_{2.5} measurement variations were observed between the PA-I Indoor sensors

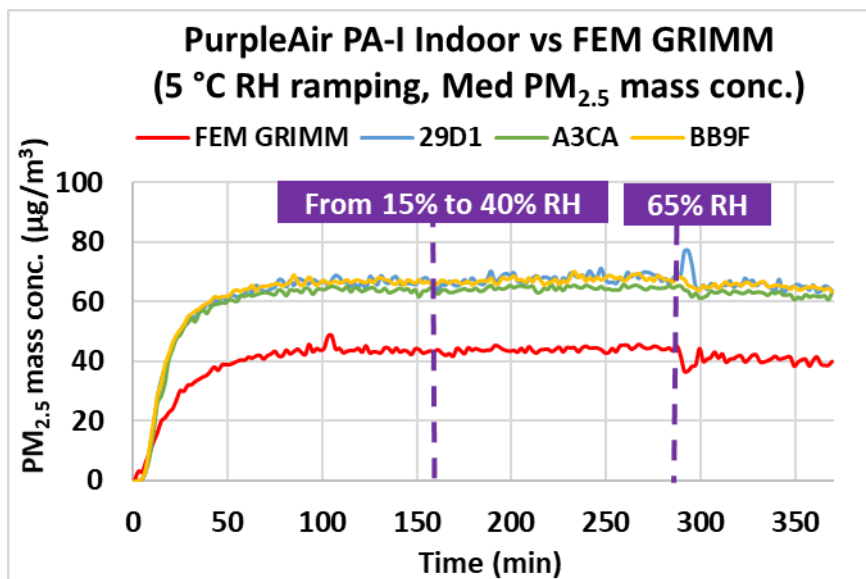
PM_{2.5} Precision: PA-I Indoor

- Precision (Effect of PM_{2.5} conc., Temperature and Relative Humidity)



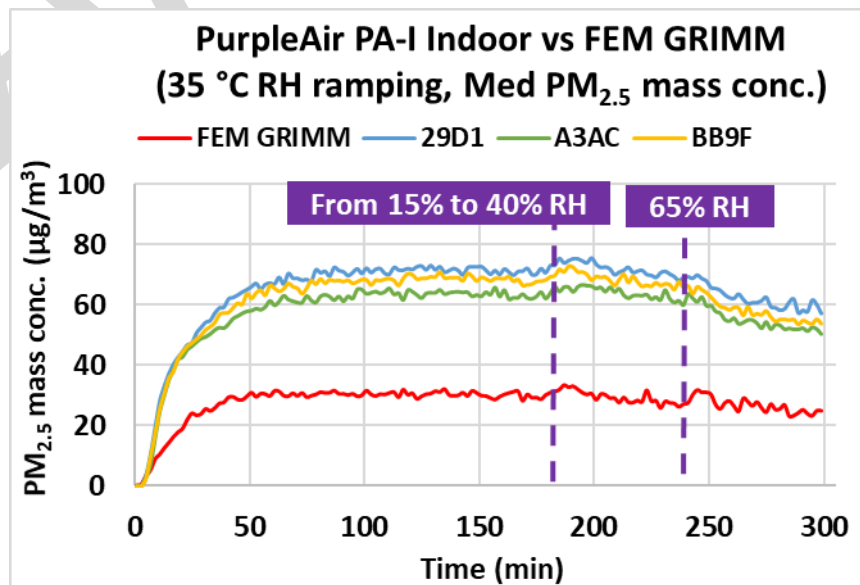
- Overall, the PA-I Indoor sensors showed high precision for all of the combinations of low, medium and high PM_{2.5} conc., T and RH.

PA-I Indoor PM_{2.5}: Climate Susceptibility



**Low Temp – RH ramping
(medium conc.)**

**High Temp – RH ramping
(medium conc.)**



Discussion (PM_{1.0} and PM_{2.5})

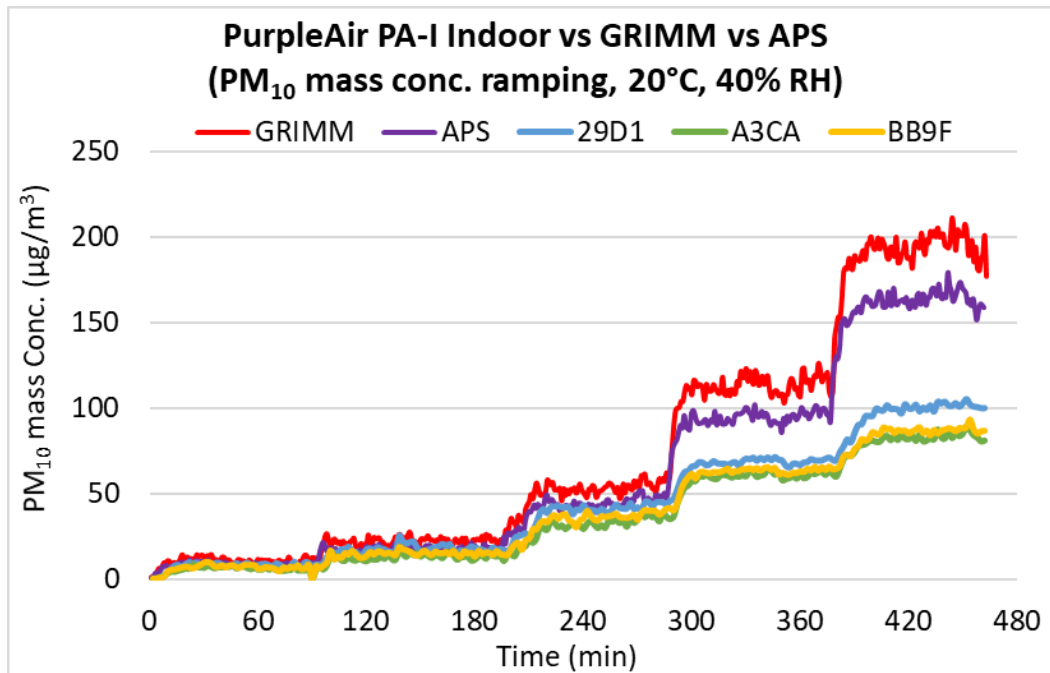
- **Accuracy:** Overall, the accuracy of the PA-I Indoor sensors increased with increasing PM_{1.0} mass concentration. The accuracy of the PA-I Indoor sensors was negative at lower PM_{2.5} mass conc. and fairly constant (48% to 57%) for PM_{2.5} mass concentrations > 50 µg/m³. The PA-I Indoor sensors underestimated PM_{1.0} at PM_{1.0} mass conc. > 50 µg/m³, while they overestimate PM_{1.0} mass conc. < 50 µg/m³. The sensors overestimated all PM_{2.5} measurements from GRIMM in the laboratory experiments at 20 °C and 40% RH.
- **Precision:** The PA-I Indoor sensors have high precision for all test combinations (PM concentrations, T and RH) for both PM_{1.0} and PM_{2.5} mass concentrations
- **Intra-model variability:** Low intra-model variability was observed among the PA-I Indoor sensors.
- **Data Recovery:** Data recovery for PM_{1.0} and PM_{2.5} mass concentration from all units was 100%.
- **Coefficient of Determination:** The PA-I Indoor sensors showed very strong correlation/linear response with the corresponding GRIMM PM_{1.0} and FEM GRIMM PM_{2.5} measurement data ($R^2 > 0.99$).
- **Climate susceptibility:** For most of the temperature and relative humidity combination, the climate condition had minimal effect on the PA-I Indoor sensors except that the sensors showed some small spiked concentration changes at the 65% RH set-point at 5°C.

Evaluation results for PM₁₀ mass concentration

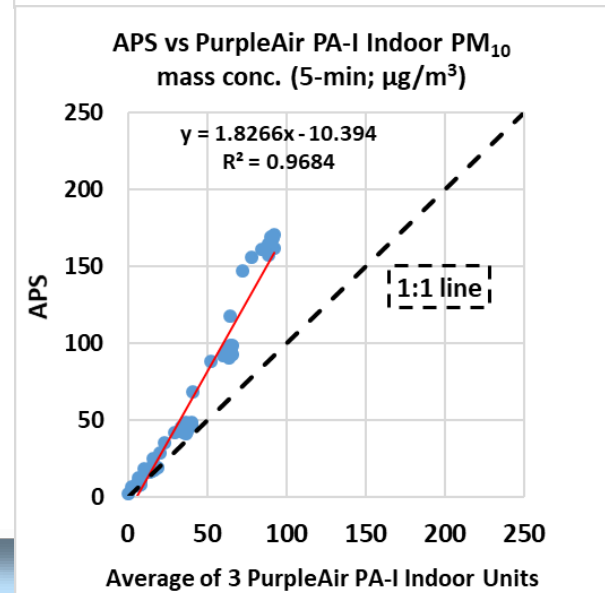
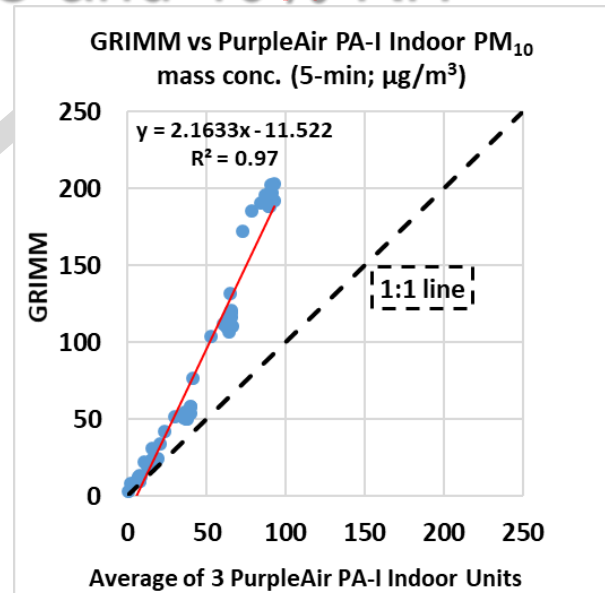
PurpleAir PA-I Indoor vs GRIMM vs APS

PA-I Indoor vs GRIMM vs APS (PM₁₀ mass conc.)

Concentration Ramping at 20 °C and 40% RH



- The PA-I Indoor sensors tracked well with the concentration variation as recorded by the APS and GRIMM in the concentration range of 0 - $\sim 200 \mu\text{g}/\text{m}^3$.
- The PA-I Indoor sensors showed very strong correlations with the corresponding GRIMM and APS PM₁₀ mass conc. ($R^2 > 0.96$).



PA-I Indoor vs GRIMM vs APS PM₁₀ Accuracy

- Accuracy (20 °C and 40% RH)

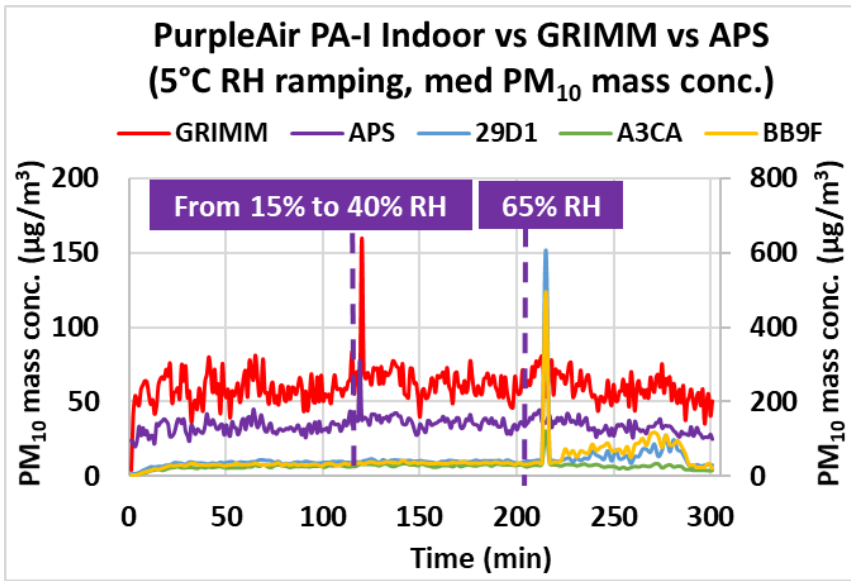
Steady state #	Sensor Mean (µg/m ³)	GRIMM (µg/m ³)	Accuracy (%)	Steady state #	Sensor Mean (µg/m ³)	APS (µg/m ³)	Accuracy (%)
1	3.6	10.1	35.2	1	3.6	7.9	45.1
2	7.6	21.8	34.9	2	7.6	17.4	43.6
3	18.0	51.5	35.0	3	18.0	42.7	42.2
4	32.5	116.9	27.8	4	32.5	86.9	37.4
5	45.1	198.5	22.7	5	45.1	166.7	27.1

- The PA-I Indoor sensors underestimated GRIMM and APS PM₁₀ mass concentration at 20 °C and 40% RH. The accuracy of the PA-I Indoor sensors decreased as PM₁₀ mass concentration increased.

PA-I Indoor : Data Recovery and intra-model variability

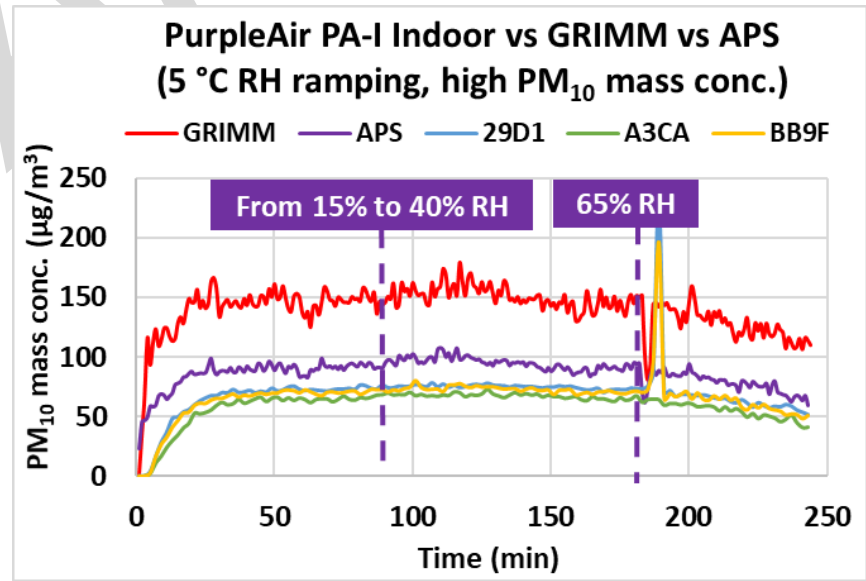
- Data recovery for PM₁₀ mass concentration from all units was 100%
- Moderate PM₁₀ measurement variations were observed between the PA-I Indoor sensors

PA-I Indoor PM₁₀: Climate Susceptibility



**Low Temp – RH ramping
(medium conc.)**

**High Temp – RH ramping
(medium conc.)**



Discussion (PM₁₀)

- **Accuracy:** Overall, the accuracy of the PA-I Indoor sensors decreased as PM₁₀ mass concentration increased. The PA-I Indoor sensors underestimated PM₁₀ mass concentrations as measured by GRIMM and APS in the laboratory experiments at 20 °C and 40% RH.
- **Precision:** Due to the nature of Arizona test dust, the aerosol concentration showed some variability, therefore, the precision cannot be fairly estimated.
- **Intra-model variability:** Moderate intra-model variability was observed among the PA-I Indoor sensors.
- **Data Recovery:** Data recovery for PM₁₀ mass concentration from all units was ~ 99%.
- **Coefficient of Determination:** The PA-I Indoor sensors showed very strong correlation/linear response with the corresponding GRIMM PM₁₀ ($R^2 = 0.97$) and APS PM₁₀ ($R^2 = 0.968$).
- **Climate susceptibility:** For most of the temperature and relative humidity combinations, the climate condition had minimal effect on the PA-I Indoor sensors except that the sensors showed spiked concentration changes at the 65% RH set-point at 5 °C.